MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2 , 2019/2020

EPM2036 – CONTROL THEORY

(RE & TE)

6 MARCH 2020
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of **6 pages** including cover page and Appendix with **4 Questions** only.

2. Attempt **ALL** questions. The distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) A control system is represented by the block diagram shown in **Figure Q1a**, where *C(s)* is the output and *R(s)* is the input of the control system.

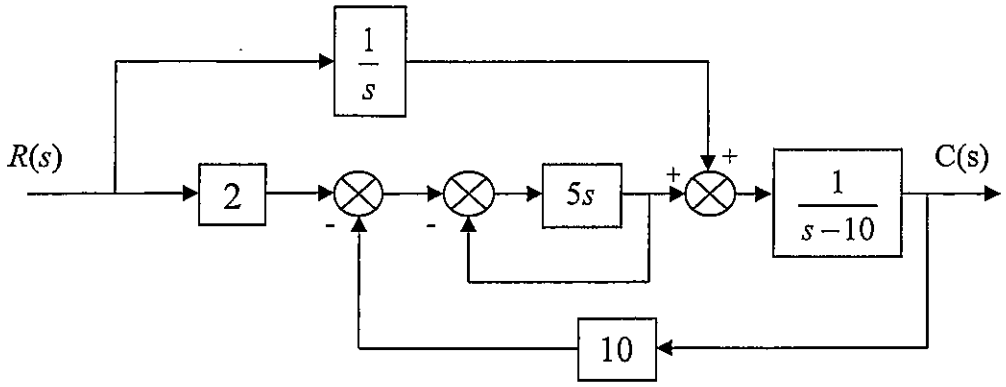

Figure Q1(a)

(i) Construct a Signal Flow Graph for the block diagram shown in **Figure Q1a**.

[5 marks]

(ii) Derive the transfer function

$$M(s) = \frac{C(s)}{R(s)}$$

using ***SFG*** and Mason's rule.

[10 marks]

(b) Determine the transfer function of G(s) = $X_2(s)/F(s)$ for the mechanical system shown in Fig. Q1 (b).

[10 marks]

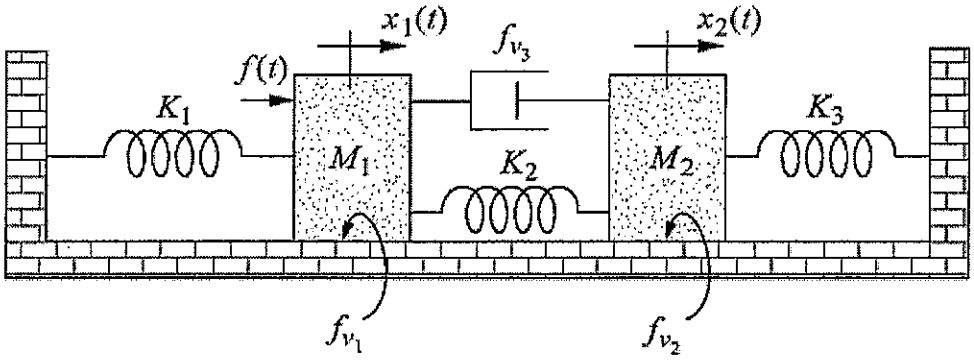

Figure Q1 (b)

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Question 2

(a) A unit-step input is applied to a unity feedback system with open loop transfer function is $G(s) = \dfrac{36}{s(s+6)}$ as shown in **Figure Q2 (a)**.

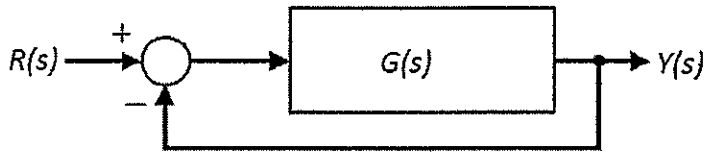

Figure Q2 (a)

Determine:

(i) The natural undamped frequency, ω_n **[4 marks]**

(ii) The damping ratio, ζ **[2 marks]**

(iii) The peak time, t_p **[2 marks]**

(b) Given a closed-loop transfer function:

$$G(s) = \frac{10}{s^5 + 2s^4 + 3s^3 + 6s^2 + 5s + 3}$$

Find the number of roots located in the left-half s-plane, right-half s-plane and on the imaginary axis with the aid of **Routh-Hurwitz** criterion.

[10 marks]

(c) A control system used in a manufacturing industry is shown in **Figure Q2 (c)**. Evaluate the static error constants and determine the steady-state error for the unit step, ramp, and parabolic inputs.

[7 marks]

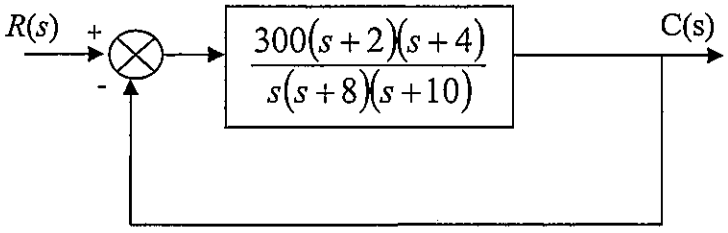

Figure Q2 (c)

Continued ...

Question 3

(a) Consider a negative unity feedback control system with the following forward path transfer function

$$G(s) = \frac{50}{s(s^2 + 8s + 15)}$$

(i) Sketch the complete Nyquist plot of G(s). Determine the intercepts with the negative real axis, if any.

[12 marks]

(ii) Determine the stability of the system based on the Nyquist Stability criterion.

[3 marks]

(b) Consider the open-loop transfer function of a control system as follow:

$$G(s) = \frac{Ks}{(s+4)(s+1+5j)(s+1-5j)}$$

(i) Calculate the system's centroid of asymptote and the angle of asymptotes.

[2 marks]

(ii) Draw the *root locus* of this system. Clearly put in the poles, zero, and the asymptotes in the graph.

[6 marks]

(iii) Calculate the *angle of departure* for the pole s = -1-5j.

[2 marks]

Continued ...

Question 4

Design a Proportional- Derivative (PD) controller to be inserted in the forward-path of the system shown in **Figure Q4** that satisfies the following performance specifications: *(Hint: You may first determine the range of K)*

- Proportional constant, $K_p = 1$
- The system with PD controller should be critically damped
- The steady state error due to input $x(t) = tu_s(s)$ should be less than or equal to 4.43×10^{-4}, where $u_s(s)$ is unit step

[25 marks]

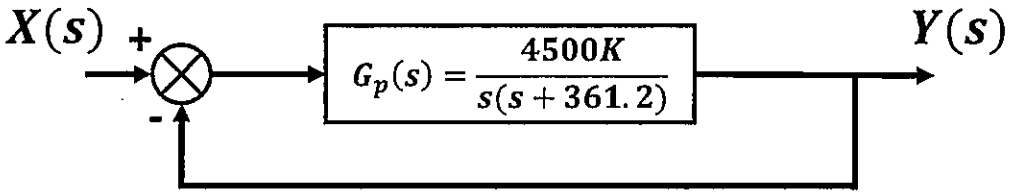

Figure Q4

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APPENDIX

TABLE: **Laplace Transform Pairs**

f(t)	F(s)
Unit impulse δ (t)	1
Unit step u(t)	$\frac{1}{s}$
t	$\frac{1}{s^2}$
$\frac{t^{n-1}}{(n-1)!}$ (n = 1, 2, 3, …)	$\frac{1}{s^n}$
t^n (n = 1, 2, 3, …)	$\frac{n!}{s^{n+1}}$
e^{-at}	$\frac{1}{s+a}$
te^{-at}	$\frac{1}{(s+a)^2}$
$\sin \omega t$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t$	$\frac{s}{s^2+\omega^2}$
$e^{-at} \sin \omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at} \cos \omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
$1-\cos \omega t$	$\frac{\omega^2}{s(s^2+\omega^2)}$
$\omega t - \sin \omega t$	$\frac{\omega^3}{s^2(s^2+\omega^2)}$
$\sin \omega t - \omega t \cos \omega t$	$\frac{2\omega^3}{(s^2+\omega^2)^2}$
$\frac{1}{2\omega} t \sin \omega t$	$\frac{s}{(s^2+\omega^2)^2}$
$t \cos \omega t$	$\frac{s^2-\omega^2}{(s^2+\omega^2)^2}$

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